"Emerging Contaminants" *in the U.S. and Region VI Waters*

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By Kim Winton, Ph.D.

Director, USGS, Oklahoma Water Science Center

USGS science for a changing world

What Are "Emerging Contaminants"?

- Emerging contaminants ("ECs") are organic compounds such as hormones, food additives, detergents, and pharmaceuticals that may occur in water.
- ECs are called "emerging" because we're just starting to discover their occurrence, methods for their analyses are experimental, and analytical method development is on-going.
- ECs are sporadically detected in parts-per-trillion concentrations.
- Human health or ecological effects from long-term exposure to such small concentrations of ECs are uncertain and may be negligible.

Steroids and Sterols

- Steroids are a large group of naturally occurring and synthetic lipids, or fat-soluble chemicals, with a great diversity of physiological activity.
- The steroid group includes certain alcohols (sterols), bile acids, many hormones, some natural drugs, and poisons found in the skin of some toads.
- Cholesterol a major contributor to arteriosclerosis, is a sterol.
- Steroid hormones, similar to but not identical with sterols, include the adrenal cortical steroids hydrocortisone, cortisone, aldosterone, and progesterone; and the female and male sex hormones estrogen and testosterone.
- Most oral contraceptives are synthetic steroids consisting of female sex hormones that inhibit ovulation.
- The most widely used steroids in medicine are cortisone and its various synthetic derivatives.

--MSN-Encarta, 2005

What about endrocrine disruption?

- Many studies conducted in the past 10 years indicate that ECs, including some pesticides, plasticizers, nonylphenols, synthetic musks, hormones, and polyaromatic hydrocarbons (PAHs) are estrogenic and can be taken up by aquatic biota.
- Increased uptake of estrogenic compounds can cause decreases in fertility, presence of both male and female hormones and reproductive organs in fish, amphibians, and rodents; and physical malformations.
- Estrogenic compounds bioaccumulate and mixtures of estrogenic compounds have additive effects.
- Zeranol (a growth promoter for beef) and estradial -17b have been linked to increased risk of breast cancer and autoimmune diseases in humans.
- Phthalates in pliable plastics have been linked to greater occurrence of female characteristics in baby boys.

Sources of Emerging Contaminants

- Wastewater Treatment Plants
- Domestic septic systems
- Industrial discharges
- Livestock CAFOs

USGS 1999 National Stream Study

139 streams sampled in 30 states--

- 62 Basins with CAFOs
- 52 Urban basins
- 17 Mixed land use basins
- 8 Minimally developed basins

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Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in U.S. Streams

A recent study by the Toxic Substances Hydrology Program of the U.S. Geological Survey (USGS) shows that a broad range of chemicals found in residential, industrial, and agricultural wastewaters commonly occurs in mixtures at low concentrations downstream from areas of intense urbanization and animal production. The chemicals include human and veterinary drugs (including antibiotics), natural and synthetic hormones, detergent metabolites, plasticizers, insecticides, and fire retardants. One or more of these chemicals were found in 80 percent of the streams sampled. Half of the streams contained 7 or more of these chemicals, and about one-third of the streams contained 10 or more of these chemicals. This study is the first national-scale examination of these organic wastewater contaminants in streams and supports the USGS mission to assess the quantity and quality of the Nation's water resources. A more complete analysis of these and other emerging water-quality issues is ongoing.

Background: Chemicals, used everyday in homes, industry and agriculture, can enter the environment in wastewater. These chemicals include human and veterinary drugs (including antibiotics), hormones, detergents, disinfectants, plasticizers, fire retardants, insecticides, and antioxidants. To assess whether these chemicals are entering our Nation's streams, the Toxic Substances Hydrology Program of the U.S. Geological Survey (USGS) collected and analyzed water samples from 139 streams

Pharmaceuticals, hormones, and other organic wastewater contaminants were measured in 139 streams during 1999 and 2000.

in 30 states during 1999 and 2000. Streams were sampled that were considered susceptible to contamination from various wastewater sources, such as those downstream from intense urbanization or livestock production. Thus, the results of this study are not considered representative of all streams.

Although each of the 95 chemicals is used extensively, there is little information about the extent or occurrence of many of these compounds in the environment. Some may be indicators of certain classes of contamination sources, such as livestock or human waste, and some have human or environmental health implications. The results of this study are a starting point for investigation of the transport of a wide range of organic wastewater contaminants in the Nation's waters.

New laboratory methods were developed in several USGS research laboratories to provide the analytical capability to measure concentrations of 95 wastewater-related organic chemicals in water. Uniform sample-collection protocols and field and laboratory quality-assurance programs were followed to ensure that results are comparable and representative of actual stream conditions.

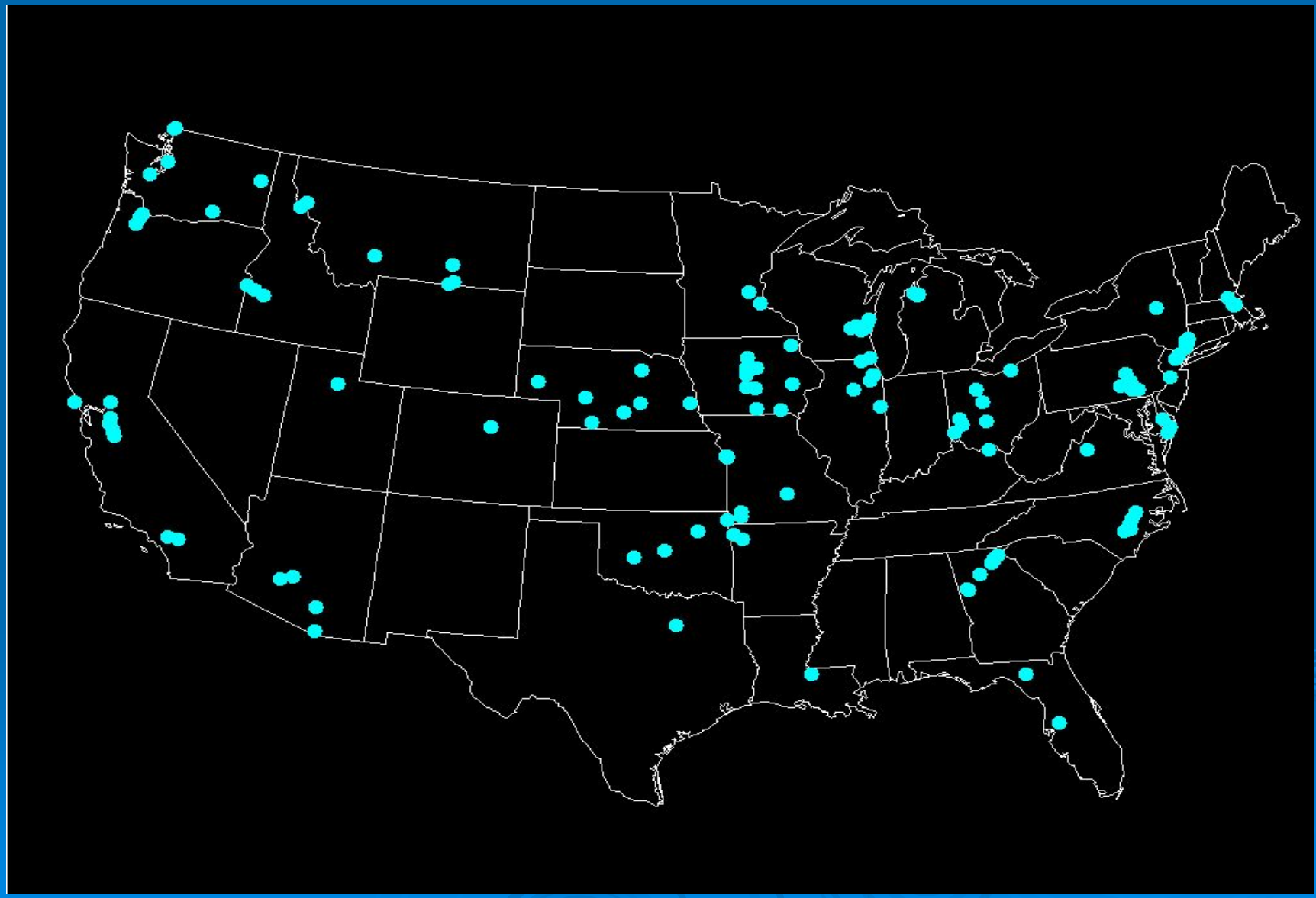
Household chemicals can enter streams through wastewater discharges. A wastewater treatment facility near Atlanta, Georgia, is shown above. (Photograph by Daniel J. Hippe, U.S. Geological Survey)

U.S. Department of the Interior
U.S. Geological Survey

USGS Fact Sheet FS-027-02
June 2002

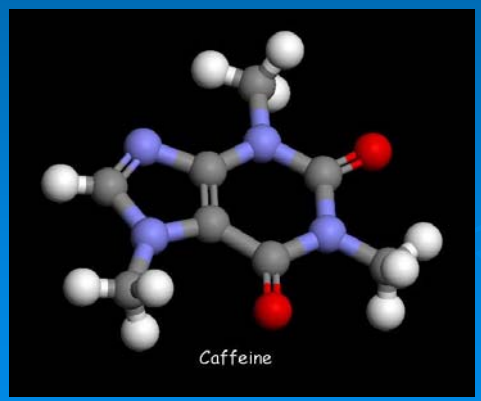
http://toxics.usgs.gov/pubs/OFR-02-94/index.html

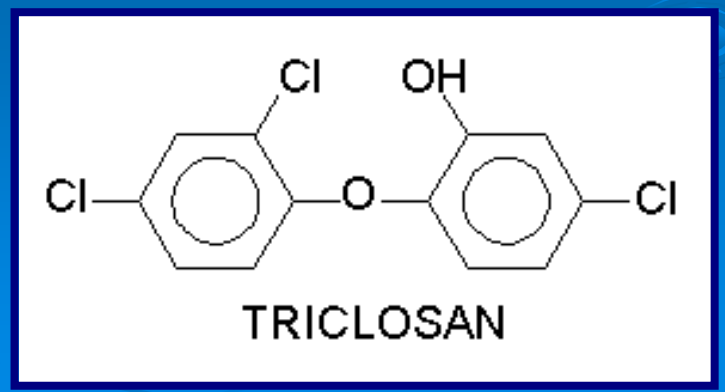
1999 National Study Monitoring Network



1999 National Study--95 Wastewater Organic Compounds (ECs) Analyzed--

- 22 Antibiotics
- 14 Prescription drugs
- 5 Nonprescription drugs
- 15 Hormones and steroids
- 39 Household and industrial compounds





1999 Ntl. Study—Results Summary

- ECs were detected in almost 80% of samples
- 82 of 95 analyzed ECs were detected
- EC concentrations were generally low:

  ~5% of the top 30 compounds were > 1 ppb
  ~25% of the sites had > 6 ppb TOTAL ECs

- Few health standards or guidelines were exceeded

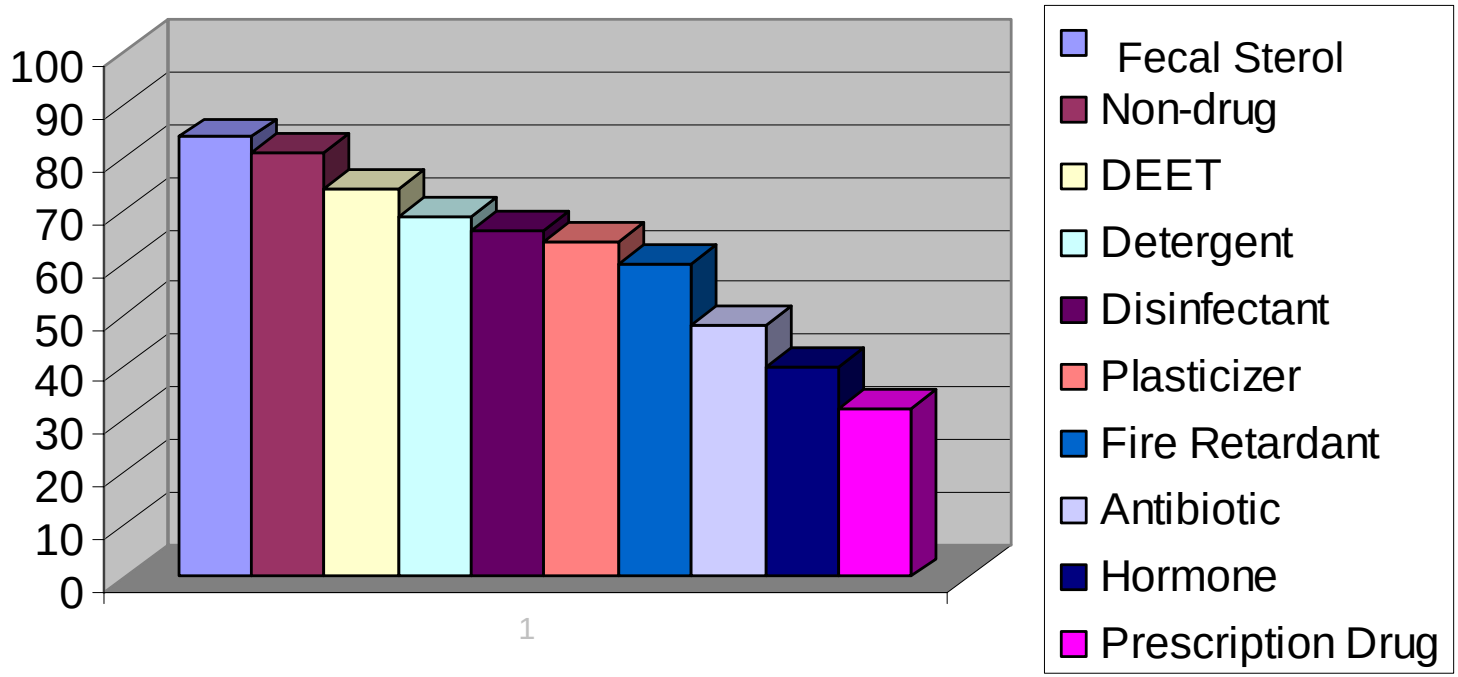
  (Only 14 of the 95 ECs had standards)

- Detection of multiple ECs was common

  34% of samples had > 10 ECs

FREQUENCY OF DETECTION OF EC GROUPS IN 1999 NATIONAL STUDY

PERCENT OF SITES WITH DETECTABLE ECs

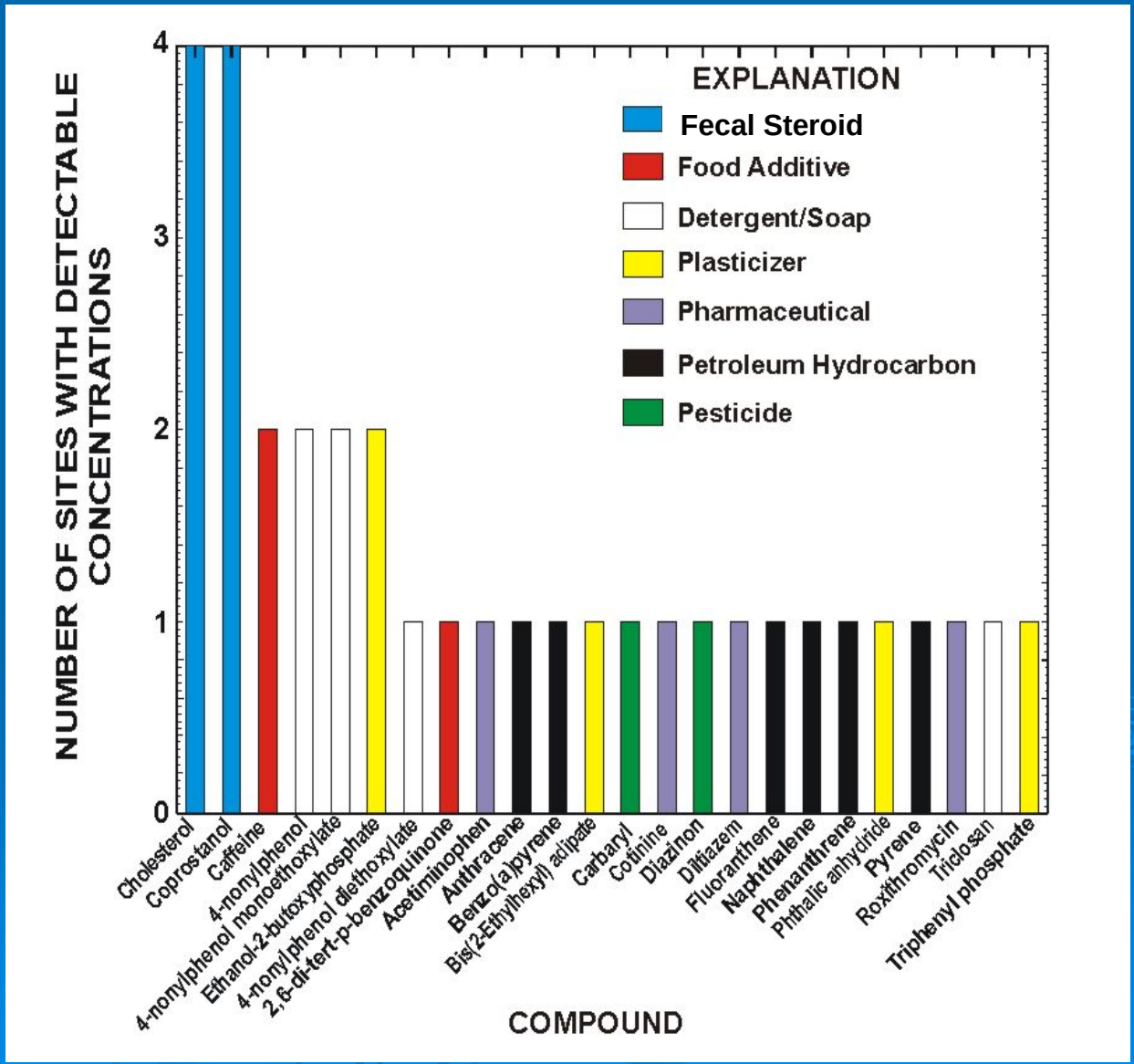


1999 NATIONAL STUDY SITES IN USEPA REGION VI

1) Willow Creek nr. Albert, OK
2) N. Canadian River nr. Harrah, OK
3) Byrd Creek nr. Catoosa, OK
4) Illinois River at Savoy, AR
5) Shumate Creek nr. Durham, AR
6) Mississippi River nr. St. Francisville, LA
7) Trinity River below Dallas, TX

1999 National Study—Frequency of EC Detection, Sites 1-4 in OK and AR

- Fecal sterols were detected at all 4 sites.
- Caffeine, soap compounds, and a plasticizer were detected at 2 sites.
- Several other types of ECs were detected at 1 of 4 sites.



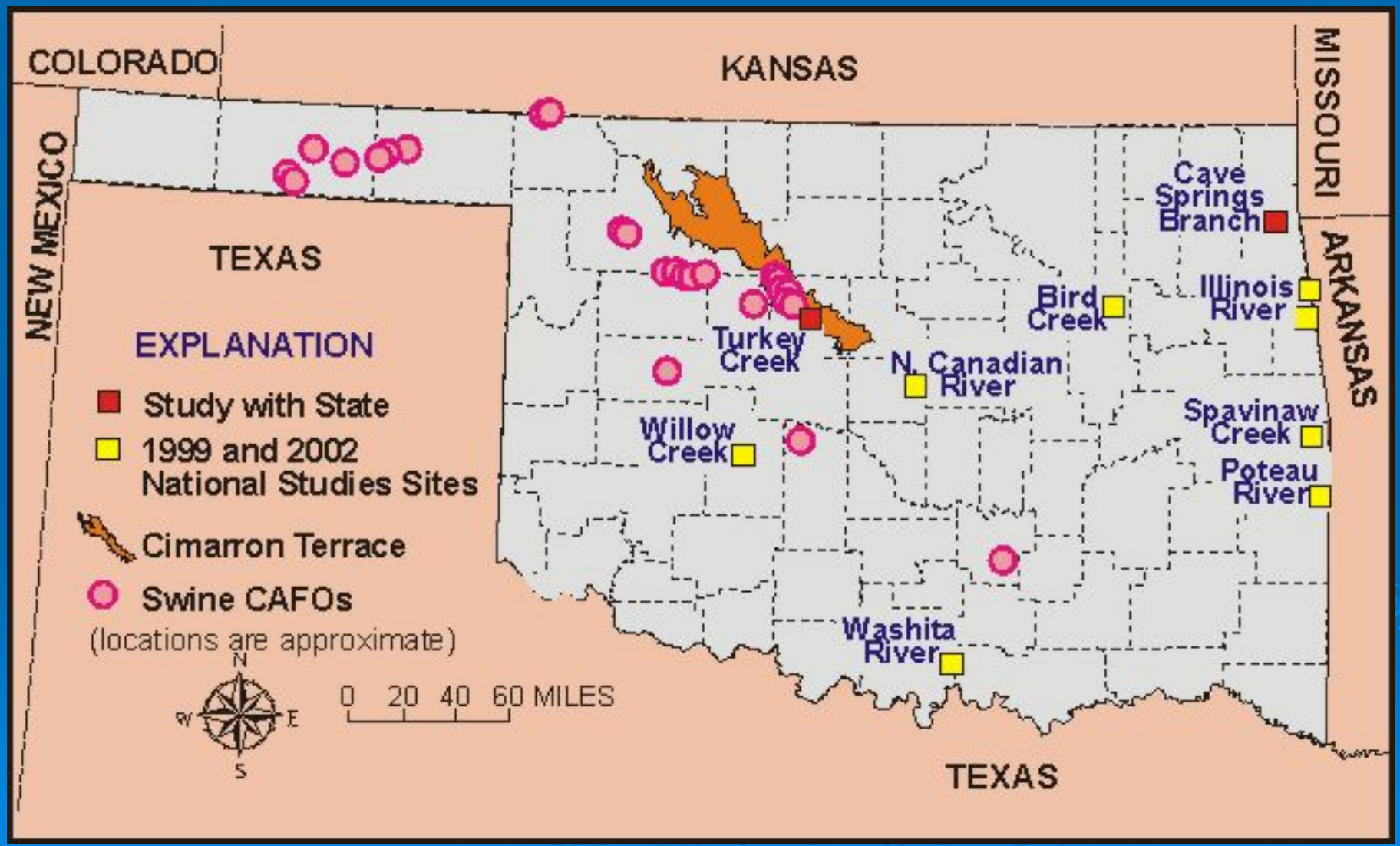
1999 National Study—ECs Detected at Site 6—Mississippi River nr. St. Francisville, LA

Lincomycin (antibiotic), 0.05 ug/L	1,4-dichlorobenzene (deodorizer) 4.3 ug/L
Roxithromycin (antibiotic) 0.05 ug/L	4-nonylphenol (detergent metabolite) 1 ug/L
Sulfamethazole (antibiotic) 0.04 ug/L	Bisphenol-A (plasticizer) 0.06 ug/L
Trimethoprim (antibiotic) 0.34 ug/L	Cholesterol (fecal sterol) 0.1 ug/L
Caffeine (stimulant) 0.068 ug/L	Coprostanol (fecal sterol) 0.005 ug/L

USGS 2002 National EC Study—A Preview

- 5 Oklahoma stream sites were sampled: Poteau River at Loving, Washita River near Dickson, Turkey Creek near Dover, Illinois River near Watts, Spavinaw Creek near Sycamore.
- New analytical methods and revisions of previous methods were used to analyze more than 100 compounds in stream water and streambed sediments.
- An article summarizing these results will be published in the near future.

Oklahoma EC Analyses Sites, as of 2005



Reconnaissance of the Hydrology, Water Quality, and Sources of Bacterial and Nutrient Contamination in the Ozark Plateaus Aquifer System and Cave Springs Branch of Honey Creek, Delaware County, Oklahoma, March 1999 - March 2000

by Schlottmann, J.L., Tanner, R., and Samadpour, M.

USGS WRIR 00-4210

In cooperation with the
State of Oklahoma Office of the Attorney General

http://pubs.usgs.gov/wri/wri004210/pdf/wri004210book.pdf

Caves Springs Branch – Types of ECs and Number of Detects

EC Compound Classes (47 analytes)	***Surface/Spring water***		***Ground water***	
	Types detected	***Total Detects***	***Types detected***	***Total Detects***
Detergent metabolites	**4**	**9**	**--**	ND
Disinfectants	**2**	**7**	**2**	**2**
Fecal Sterols	**3**	**7**	**2**	**2**
Fire retardants	**1**	**4**	**1**	**2**
Fragrance	**1**	**2**	**1**	**2**
Fumigants	**2**	**6**	**--**	ND
Stimulants	**2**	**8**	**1**	**3**
Plasticizers	**5**	**7**	**3**	**5**
Preservatives	**2**	**9**	**1**	**1**
PAHs	**3**	**4**	**1**	**1**

Reconnaissance of Surface-Water Quality and Possible Sources of Nutrients and Bacteria in the Turkey Creek Watershed, Northwest Oklahoma, 2002-2003

by Carol Becker, Hydrologist

In cooperation with the Oklahoma Department of Environmental Quality

Turkey Creek, July 28 and 29, 1999

EC compound classes (47 analytes)	***Surface water***		***Ground water***	
	Types detected	***Total Detects***	***Types detected***	***Total Detects***
Detergents & metabolites	**1**	**6**	**--**	**ND**
Disinfectants	**1**	**1**	**--**	**ND**
Fecal Sterols	**1**	**6**	**--**	**ND**
Fire retardant	**1**	**5**	**--**	**ND**
Stimulants	**1**	**5**	**1**	**1**
Plasticizers	**2**	**3**	**1**	**1**
Preservative	**1**	**1**	**1**	**1**
PAHs	**4**	**4**	**--**	**ND**

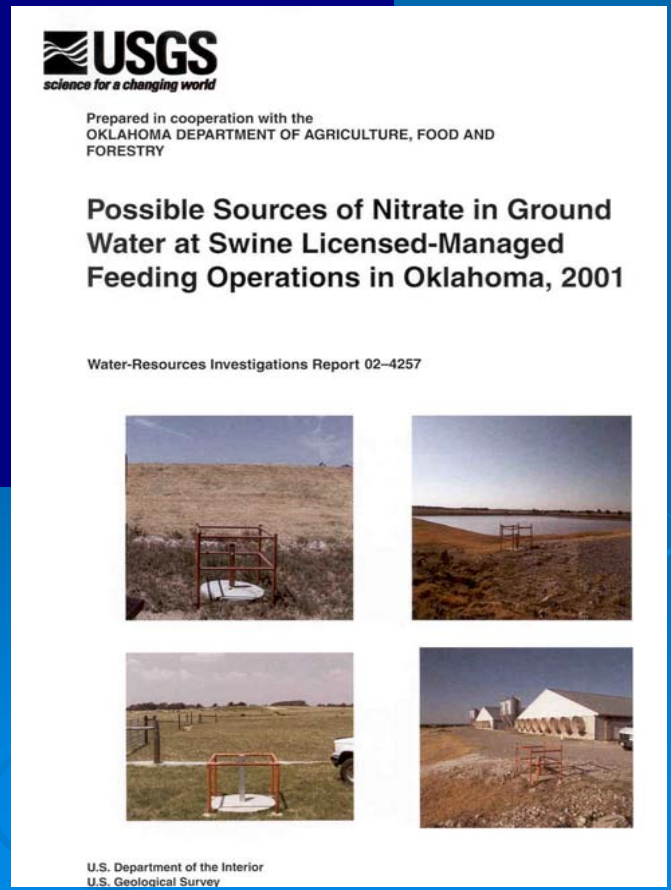
Possible Sources of Nitrate in Ground Water at Swine Licensed-Managed Feeding Operations in Oklahoma, 2001

by. Becker, M.F., Peter, K.D., and Masoner, J.R.

USGS Water Resources Investigations Report 02-4257

In cooperation with the
Oklahoma Department of Agriculture, Food and Forestry

http://pubs.usgs.gov/wri/wri024257/



Swine Lagoons and Monitoring Wells – Types of ECs and Number of Detects

EC compound classes ***(67 analytes)***	*Swine lagoons*		*Monitoring wells*	
	Types detected	*Total detects*	*Types detected*	*Total detects*
Fecal sterols	**7**	**38**	**7**	**28**
Detergents & metabolites	**2**	**4**	**1**	**9**
Household	**12**	**32**	**10**	**66**
Industrial	**2**	**12**	**2**	**3**
PAHs	**3**	**3**	**4**	**16**
Pesticides	**--**	ND	**1**	**7**

Water Quality and Possible Sources of Nitrate in the Cimarron Terrace Aquifer, Oklahoma, 2003

By Masoner, J.R., and Mashburn, S.

USGS Scientific Investigations Report 2004-5221

In cooperation with the
Oklahoma Dept. of Environmental Quality

http://pubs.usgs.gov/sir/2004/5221/

Cimarron Terrace Aquifer – Types of ECs, Number of Detections, and Number of Wells with Detectable ECs

EC Compound Classes (72 analytes)	*Types detected*	*Total detects*	*Number of wells having detects*
Fecal sterols	1	1	1
Detergents	1	2	2
Household	11	43	27
Hydrocarbon	3	7	3
Industrial	2	2	2
Pesticides	8	35	19

Occurrence of Pharmaceutical and Other Organic Wastewater Constituents in Selected Streams in Northern Arkansas, 2004

USGS Scientific Investigations Report 2005-5140

By Galloway, J., and others

In Cooperation with: University of Arkansas & U.S. Department of Agriculture, Agricultural Research Service

http://pubs.usgs.gov/sir/2005/5140/

Occurrence of ECs in selected streams in Northwest Arkansas, 2004

- Sampled 7 sites upstream and 10 sites downstream of wastewater treatment facilities and 1 background site.

ECs detected (108 analytes)

- All but one site had at least one detectable EC.
- Upstream sites averaged 3 detectable ECs.
- Downstream sites averaged 14 detectable ECs.
- 7 downstream sites had >12 detectable ECs.
- Background site had 3 detectable ECs.

ECs with 5 or More Detections

Antibiotics	Anhydro-erythromycin	5
	Trimethoprim	5
Detergent metabolites	Nonylphenol, diethoxy- (total NPEO2)	7
	Octylphenol, diethoxy –(OPEO2)	6
	Para-Nonylphenol (total)	6
Disinfectants	Para-Cresol	15
	Bromoform	5
	Phenol	18
	Triclosan	5
Flame retardants	Tri(2-chloroethyl) phosphate	10
	Tri(dichloroisopropyl) phosphate	9
	Tributyl phosphate	9

ECs with 5 or more detections -- continued

Fragrance/ Flavor	Acetyl hexamethyl tetrahydro naphthalene (AHTN)	13
	Benzophenone	9
Insect repellant	N,N-diethyl-meta-tolumide (DEET)	10
Non-prescription drugs	Caffeine	17
Flame retardants	Triethyl citrate (ethyl citrate)	9
	Triphenyl phosphate	9
Fecal Sterols	3-beta-Coprostanol	6
	Cholesterol	6

Final Thoughts

- "Emerging Contaminants" may be useful indicators of possible sources of accompanying chemicals, such as nitrate or phosphorus.
- "Emerging Contaminants" may or may not be conservative in hydrologic systems.
- Health effects of mixtures of low concentrations of ECs on wildlife or humans are not known, but antibiotic resistance in bacteria is common, as are endocrine-disrupting effects in fish and amphibians.
- Pharmaceuticals may be the next recharge/discharge age-dating tool.

Thank you for your time!

Cited reports available at http://ok.water.usgs.gov/bib_list.html